telescopic observations. It would seem that the telescope has scarcely been applied to it since the time of the elder Cassini. The Spectroscope has not been applied to it at all. But if these views are correct, when it shall be spectroscopically examined under favourable circumstances, (which cannot perhaps, be expected to occur in these climates, always seen in part as it must be through the least transparent strata of our atmosphere) the Zodiacal Light should yield a monochromatic spectrum, with bright lines making known the chemical composition of its gaseous portion. Some of the meteoritic masses which traverse it may very probably be themselves in a denser gaseous state, like the nucleus of a Comet, others will have become liquid or solid, and the collective glare of all these particles may be expected to give a faint continuous spectrum in addition.

It would be disingenuous in me, on account of several remarks which I have offered in the course of this Note, were I now to omit the announcement of my having arrived at the conclusion, that in all probability the bright-line or monochromatic spectra, from which Mr. Huggins has inferred the gaseous constitution of certain Nebulæ, are due in reality to the luminous atmospheres of their constituent Stars or Suns. I am about to submit to the Royal Society a paper in which the grounds of that conclusion will be stated.

London Institution, June 14th, 1867.

On the connexion between Comets and Meteors.
By G. Johnstone Stoney, M.A., F.R.S.

The astonishing fact which Sig. Schiaparelli brought to light some months ago, that there are comets moving in the tracks of the August and November meteors, compels us to infer that there is some intimate physical connexion between the two. In January last, M. Leverrier pointed out that such stream of meteors must have been in compact clusters when they underwent the great perturbations which brought them into permanent connexion with the Solar System. And Mr. Graham has lately shown that the meteoric iron which reaches our Earth had been at some previous time red-hot; and that when last red-hot it was acted on by hydrogen under considerable pressure—a pressure of perhaps six or more atmospheres. It is my present design to make use of these inferences as data,

and to endeavour to trace by their help, what the physical connexion between the comets and the meteors has been.

If interstellar space, external to the Solar System, be, as is most probable, peopled with innumerable meteoric bodies independent of one another, a comet while outside the Solar System would in the lapse of ages collect a vast cluster of such meteorites within itself. Each meteorite which approached the comet would in general do so in a parabolic orbit; and, if it came near enough to pass through a part of the comet, this parabolic orbit would by the resistance of the matter of the comet be converted into an ellipse. The meteor would therefore return again and again, and on each occasion that it passed through the comet its orbit would be still further shortened, until at length it would fall in, and add one to whatever cluster had been brought together by the previous repetitions of this process.* In this way, a comet while moving in outer space, beyond the reach of the many powerful disturbing influences which prevail within the Solar System, would inevitably accumulate within itself just such a globular cluster of meteorites as the November meteors must have been before they became associated with the Solar System.

When this body of meteors, enveloped by their comet, swept past the planet *Uranus* in the year 126, they may have come so close, that the comet brushed against the atmosphere of the planet. If this took place the comet must have both received a motion of rotation and been retarded.† The meteorites at its centre, retaining their speed, would accordingly gradually pass out through it and leave it a little behind; and when all got so far from the planet as to be beyond its further influence, the comet would be found moving round the Sun with a shorter periodic time than the meteors. This is in conformity with Dr. Oppolzer's determination of the periodic

* The behaviour described in the text is a consequence of the familiar formula for elliptic motion

$$V^2 = \frac{2\mu}{r} - \frac{\mu}{a},$$

since if at any distance r a resistance be experienced, V is thereby diminished, and as the formula must still hold good, a is also shortened.

† The cluster appears to have approached the orbit of *Uranus* from the outside, and, after passing the planet, to have described a relative orbit directed a little inwards towards the Sun, but principally backwards, *i.e.* in a direction the reverse of the planet's motion, with a relative velocity greater than the velocity of the planet. It in this way acquired a slow absolute motion, which was directed both inwards and backwards, and was thus started in its retrograde orbit round the Sun. A slight brush of the comet against the planet would both somewhat increase the curvature of the relative orbit, and slacken the comet's pace along it; and either of these effects would, under the circumstances which have been described, result in such a diminished absolute velocity as is attributed to the comet in the text.

time of the comet, viz. 33·18 years, that of the meteors being 33·25.*

The discovery of the Master of the Mint becomes now of exceeding interest, since it seems to show, first, that hydrogen is one of the constituents of comets; secondly, that the meteoric bodies he examined, when they originally joined their comet, fell in with a velocity sufficient to raise them, by the friction they suffered, to a red heat; thirdly, that the density of the comet was sufficient to occasion, in front of the advancing meteorite, a pressure of several atmospheres; fourthly, that when the meteors and the comet afterwards parted company, they glided asunder so quietly that the meteors were not again raised to any very high temperature; and, finally, that the friction they again encountered in passing through the Earth's atmosphere, was not sufficiently protracted to raise their internal parts to a red heat.

When the cluster of November meteors passed the planet which diverted them into the Solar System, they were unequally acted on by it, the path of those which lay nearest being most bent. To this, as M. Leverrier has remarked, is to be referred their subsequently moving in slightly differing orbits, with slightly different periodic times round the Sun, which after the lapse of many revolutions has gradually extended them along their nearly common path, and will as time goes on still further lengthen out the stream. Hence the feeble gravity of the comet was not sufficient to restrain the meteors which were originally within it from yielding to these weak forces. The gravity of the comet accordingly cannot have been what kept the parts of its own mass from giving way to the same influences, and being (like the meteors) drawn out into a long thread. This is one of several considerations,† which

* It should be remarked, however, that the comet seems to have fallen nearly a revolution behind the meteors since A.D. 126, *i.e.* in 52¼ revolutions. If this be so, its periodic time must be less than Dr. Oppolzer's estimate, and is probably about 32·63 years; unless we may suppose that since its introduction into the Solar System, it has suffered a perturbation which has diminished its mean motion round the Sun. Such a perturbation is not impossible—it would arise, for instance, if a swifter stream of meteors overtook the comet and passed through it; and it is easy to assure one's self that a swarm of meteors having the requisite direction and speed to behave thus, may have been drawn into the Solar System by any one of the planets *Jupiter*, *Saturn*, *Uranus*, or *Neptune*.

It is not without interest to observe that whether the periodic time of the comet be 33·18 years or less, it will, before its next perihelion passage, have been run into by the meteors. The effect of this would seem to be first to accelerate the comet at the expense of some of the *vis-viva* of the meteors which pass through it; and finally, when the motion of the comet has been brought sufficiently into accordance with that of the meteors, to cause a gradual accumulation at the centre of the comet of those meteors which then happen to lie within the space occupied by it.

† Other grounds for this belief will be found in a Memoir on the Physical Constitution of the Sun and Stars, lately submitted to the Royal Society.

disturbing influence of the Earth or other small planet has occasioned, are probably, for the most part, the *débris* of streams which at one time were moving with a *direct* motion round the Sun.

Since we have now abundant reason to believe that the great circular stratum within which the members of the Solar System lie, is traversed in all directions by numbers of these meteoric bodies, so vast that, as Professor Newton has computed, $7\frac{1}{2}$ millions large enough to be visible to the naked eye on a clear night, and 40 times that number of smaller ones, enter the the Earth's atmosphere daily, we are no longer called on to assume the existence of a resisting medium, or of a departure from the law of gravitation, to account for the retardation of comets. Meteors passing through a comet indifferently in all directions, and with the same absolute speed, would operate upon it like a resisting medium.

Introducing these numbers we find that

$$a = \frac{22400}{324000} \cdot \frac{1}{(2 \cdot 4)^2} = \frac{1}{83}.$$

Now the deflection of a meteor's path in its relative orbit $= 2 \operatorname{cosec}^{-1} \dfrac{c}{a}$, and will of course be greatest when the meteor almost grazes the Earth's atmosphere, *i.e.* when $c - a = 1$.

Therefore the maximum deflection $= 2 \operatorname{cosec}^{-1} 84 = 1^\circ\, 22'$. This is the deflection as seen from the Earth, and corresponds to an absolute deflection in space of $2^\circ\, 20'$.

On the other hand, in the case of a meteor overtaking and passing the Earth,

$$a = \frac{22400}{324000} \cdot \frac{1}{(0 \cdot 4)^2} = \frac{1}{2 \cdot 314},$$

therefore the maximum deflection as seen from the Earth

$$= 2 \operatorname{cosec}^{-1} 3 \cdot 314 = 35^\circ,$$

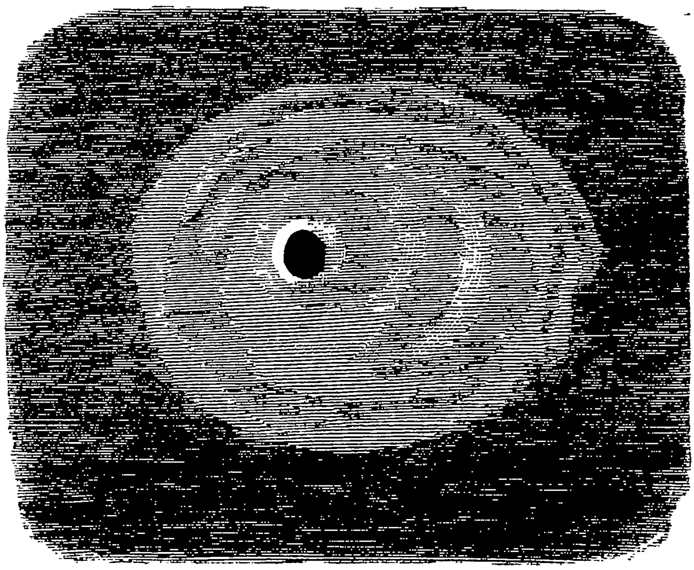
which corresponds to an an absolute deflection of 50°.

The difference between these deflections far more than compensates for the circumstance that the Earth would come across, and therefore have an opportunity of deflecting, about six times as many members of a retrograde swarm of meteors, as of a similar one travelling in a direct orbit.

Note on the Lunar Crater Linné.
By William Huggins, Esq., F.R.S.

The diagram which accompanies this note represents the Crater *Linné* as it appeared in the telescope on May 11th, 1867. The unusual steadiness of the atmosphere permitted the small Crater upon *Linné* to be seen with great distinctness.

May 11th, 1867.



8h. 45m.

Linné on this occasion presented the appearance of an oval white patch on the darker background of the *Mare Serenitatis*. The character of the surface of the white spot may be described as similar in appearance to that of a cloud, for it presented no distinct details, and remained undefined when the small neighbouring craters were seen with great clearness. The absence of any defined points upon which the eye can rest is probably the reason that the "boiling" motion of our atmosphere is perceived in a much more marked manner over the white spot, than on the adjoining sharply defined parts of the Moon's surface. From this cause *Linné* appeared, on several occasions, as a mass of white cloud in motion, at the same time that the craters near it were seen steadily and with distinctness. This cloudy appearance arises probably from a peculiar, partly reflective property of the material of which *Linné* consists. Some other portions of the Moon's surface reflect light in an analogous manner.

At the time when the diagram was made, the shallow, saucer-like form of *Linné* was not seen, but I have detected it on other occasions. On the evening of July 8, at 7^h, when

a great part of the light reflected from our atmosphere was removed by means of a Nicol's prism placed next to the eye, I observed a shadow within the western margin of the shallow crater.

In the centre nearly of *Linné*, but rather nearer to the western margin, was seen the small Crater, as it is represented in the diagram.* This object was well defined in the telescope. The interior of the small Crater was in shadow, with the exception of a small part of it towards the east. The margin of the small Crater was much brighter on the western side, and at this part appears to be more elevated above the surface of *Linné*. Under very oblique illumination this high western wall appears as a small brilliant eminence, and casts a shadow which is somewhat pointed. In consequence of the presence of visitors in my observatory, I did not take measures of the small Crater. I estimated its diameter to be rather greater than one-fourth of the diameter of the white spot.

On the evening of July 9, at 9^h, the following measures were taken of *Linné*, and of the small interior crater. Under a power of 500 diameters, with which the measures were made, the boundary of *Linné* does not end abruptly, but passes gradually into the darker surface of the *Mare Serenitatis*. The white spot is oblong, but is not a regularly formed oval. At some parts of its outline small projecting portions of the bright surface interrupt the regularity of its figure.

The small crater, which appears to be deep, has a narrow margin, brighter than the white spot on which it occurs. The measures of this crater include the narrow, bright margin.

Length of the bright spot	$7''.85$
Breadth	6.14
Diameter of the small centre ..	1.71

1866, Dec. 14th. I observed the Moon with a Savart's polariscope attached to the telescope. The coloured bands passed unbroken across *Linné*, which appeared at the time as a white spot. Also when a double-image prism and plate of quartz were used, *Linné* was coloured similarly to the adjoining parts. The light from *Linné* contained a smaller amount of polarized light.

1867, Feb. 14th. I examined carefully the spectrum of the light reflected from *Linné*. The small size of the object makes this observation somewhat uncertain. The lines of Fraunhofer were seen with great distinctness in the spectrum of the Moon's light; but I failed to detect any lines which do not belong to solar light, in the narrow, brighter spectrum which was formed by the light from *Linné*.

Herr Schmidt is of opinion that a great change has recently taken place in the appearance of *Linné*, when it is viewed

* In the woodcut, the crater is a little too small in proportion to the white spot.

under oblique illumination. This conclusion is based upon a comparison of its present appearance with the descriptions of Lohrmann and Mädler, and with Herr Schmidt's own observations from 1841 to 1843.*

On this account it is of importance to note that the earlier observations by Schröter seem to agree very closely with the appearance which *Linné* now presents.

In Plate IX. of Schröter's *Selenotopographische Fragmente* the place occupied by *Linné* is marked by a round white spot, and not by the figure of a Crater. This white spot is a little smaller than the figure of the Crater *Sulpicius Gallus.* The spot is distinguished on the Plate by the letter *v.*

At page 181, Schröter gives the following description of this object: "Die sechste Bergader kommt von einer fast dicht an den südlichen Gränzgebirgen befindlichen, verhältlich gezeichneten Einsenkung *u*, streicht nördlich nach *v*, *woselbst sie wieder eine ohngefähr gleich grosse, aber ganz flache, als ein weisses, sehr kleines rundes Fleckgen erscheinende, etwas ungewisse Einsenkung in sich hat* . . . . "

I have put in Italics the words which apply to *Linné*. The observation was made, 1788, Nov. 5th, from $4^h\ 30^m$ to 8^h. The mean time of the observations was 7 days 14 hours after new Moon. Schröter employed a power of 161 on his 7-foot reflector.†

The description of this object as "a flat, somewhat doubtful Crater, which appears as a round white spot," agrees remarkably with the appearance which *Linné* now presents under similar conditions of illumination. The absence of any mention by Schröter of the small interior Crater, cannot be regarded as evidence of much weight, that this little Crater has been subsequently formed. An object so small might easily have been overlooked by Schröter. However, Lohrmann's description, in 1823,‡ and that of Mädler in 1831, do not appear to be in accordance with Schröter's observations, or with the present condition of the object.§ The observations were made with a refractor of 8 inches aperture, and with various powers from 200 diameters to 800 diameters.

* *Monthly Notices*, vol. xxvii. p. 93. *Ast. Nachrichten*, No. 1631. *Sitzungsberichte der K. Akademie, Wien*, Bd. lv., Feb. 1867.

† For his *measures* of the *Mare Serenitatis*, Schröter employed a reduced power of 95 diameters. In his second volume, at page 276, he gives an account of a re-examination of this part of the Moon's surface with more powerful telescopes. On this occasion (see Tab. LXIX.) *Linné* was not observed, probably because it was too close to the terminator. Schröter remarks, " . . . indem noch nicht einmahl die ganze Fläche erleuchtet war, sondern die Lichtgränze östlich durch sie vor den östlichen Gränzgebirgen weg lag."

‡ " A is the second Crater upon this plain—has a diameter which exceeds somewhat 1 mile, is very deep, and can be seen under every illumination." *Topographie der Mondoberflache*, p. 92, and Plate, Section IV.

§ A series of careful observations has been made by Prof. Respighi, *Les Mondes*, 13 Juin, 1867. See also observations of M. Flammarion, *Comptes Rendus*, Mai 20, 1867, and of M. Wolf, *Comptes Rendus*, Juin 17, 1867.